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(54) **SYSTEM AND METHODS FOR VEHICLE ALIGNMENT CONTROL**

(71) Applicant: **Ford Global Technologies, LLC**, Dearborn, MI (US)

(72) Inventors: **Luke Niewiadomski**, Dearborn, MI (US); **Li Xu**, Northville, MI (US)

(73) Assignee: **Ford Global Technologies, LLC**, Dearborn, MI (US)

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(51) **Int. Cl.**

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B60W 10/18	(2012.01)
B60W 10/20	(2006.01)
B60D 1/06	(2006.01)

(52) **U.S. Cl.**

CPC ***B60D 1/366*** (2013.01); ***B60W 10/18*** (2013.01); ***B60W 10/20*** (2013.01); *B60D 1/065* (2013.01); *B60W 2520/10* (2013.01); *B60W 2754/30* (2020.02)

(58) **Field of Classification Search**

CPC B60D 1/366; B60D 1/065; B60W 10/20; B60W 10/18; B60W 2754/30; B60W 2520/10

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,970,184	B2	11/2005	Hirama et al.	
8,350,684	B2	1/2013	McClure	
8,665,078	B2	3/2014	Van Wiemeersch et al.	
9,102,271	B2	8/2015	Trombley et al.	
9,315,175	B1 *	4/2016	Reed	B60T 8/171
9,499,018	B2	11/2016	Gehrke et al.	
9,914,333	B2	3/2018	Shank et al.	
2005/0017855	A1 *	1/2005	Harvey	G08G 1/207 340/426.1
2008/0054598	A1 *	3/2008	Weber	B60D 1/665 280/475
2013/0226390	A1 *	8/2013	Luo	B60D 1/36 348/148
2015/0066328	A1 *	3/2015	Nakada	B62B 9/02 701/93
2017/0151846	A1 *	6/2017	Wuergler	B62D 15/029
2018/0253106	A1 *	9/2018	Inui	B60D 1/06
2018/0312022	A1	11/2018	Mattern et al.	
2019/0299947	A1 *	10/2019	Higashitani	B60T 8/1708
2019/0339704	A1 *	11/2019	Yu	G06T 7/174
2020/0039517	A1 *	2/2020	Berkemeier	G05D 1/0231

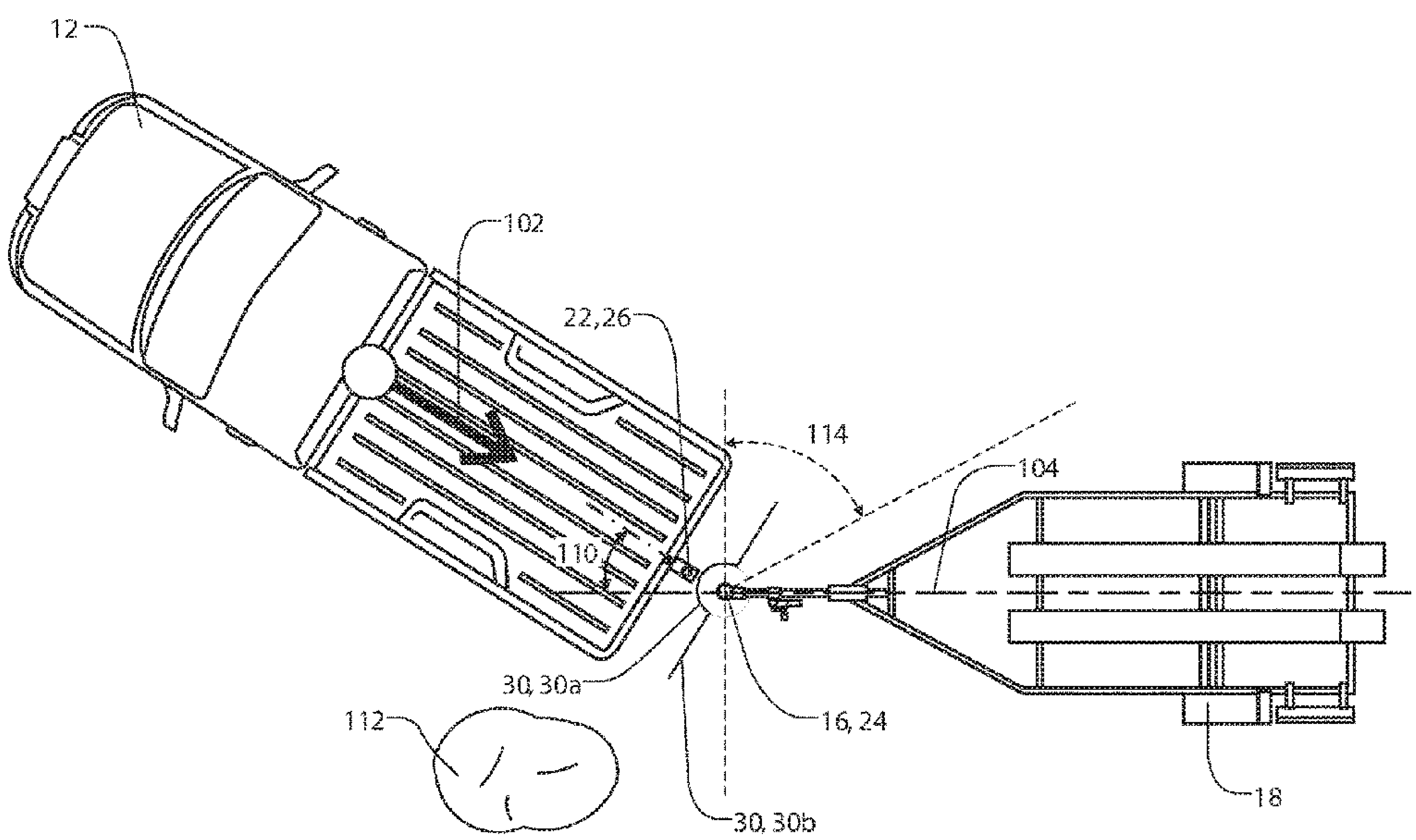
* cited by examiner

Primary Examiner — Jelani A Smith
Assistant Examiner — Toya Pettiegrew
(74) *Attorney, Agent, or Firm* — Gregory Brown; Price Heneveld LLP

(57) **ABSTRACT**

A vehicle system configured to control a trailer alignment routine comprises a hitch mounted on a vehicle and a controller. The controller is configured to identify a coupler position of a trailer and control motion of the vehicle toward an aligned position. The controller is further configured to calculate a stopping threshold relative to the coupler position. The stopping threshold comprises a semicircle concentric to the coupler position. The controller is further configured to control a braking procedure in response to the hitch passing the stopping threshold.

16 Claims, 7 Drawing Sheets



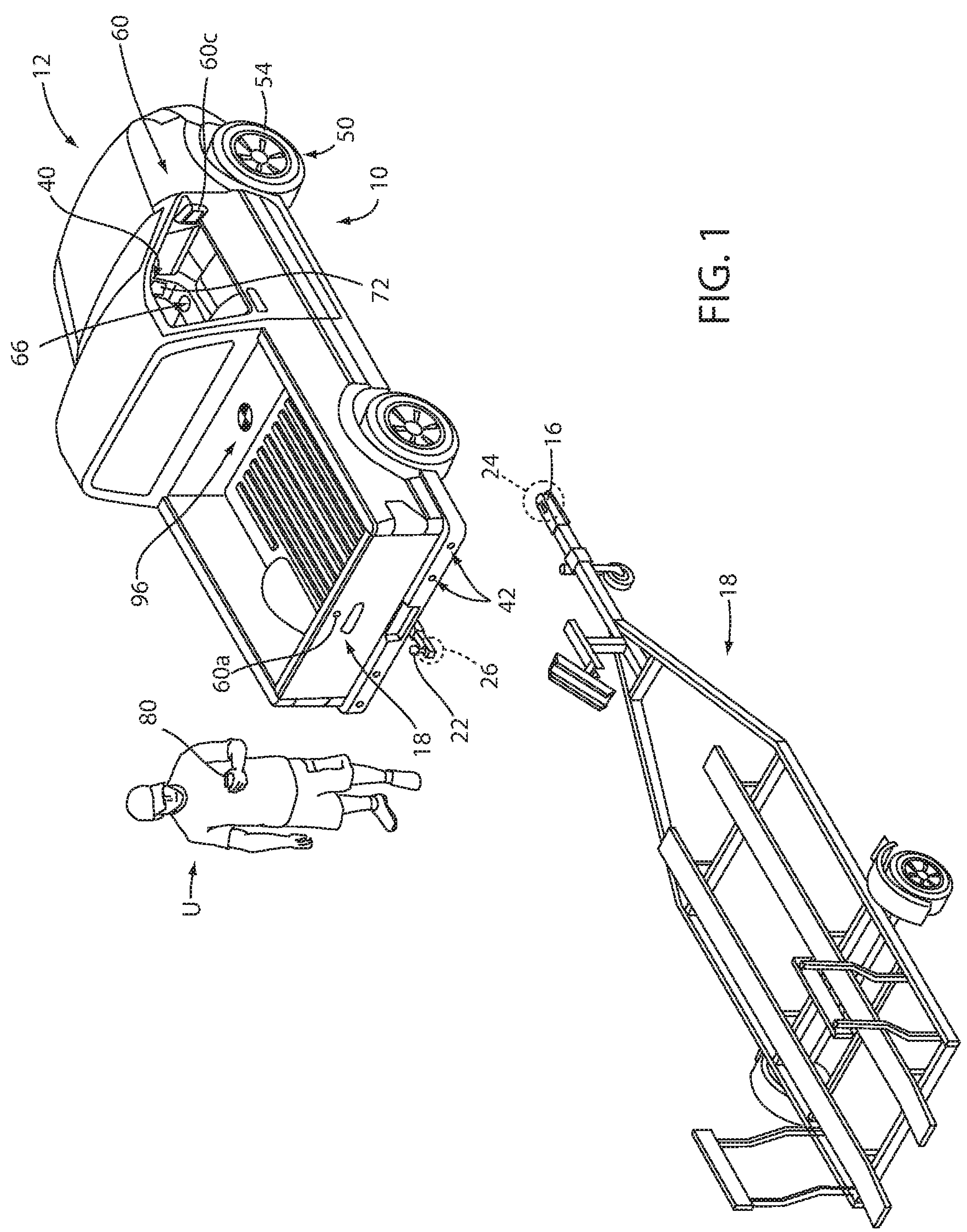


FIG. 1

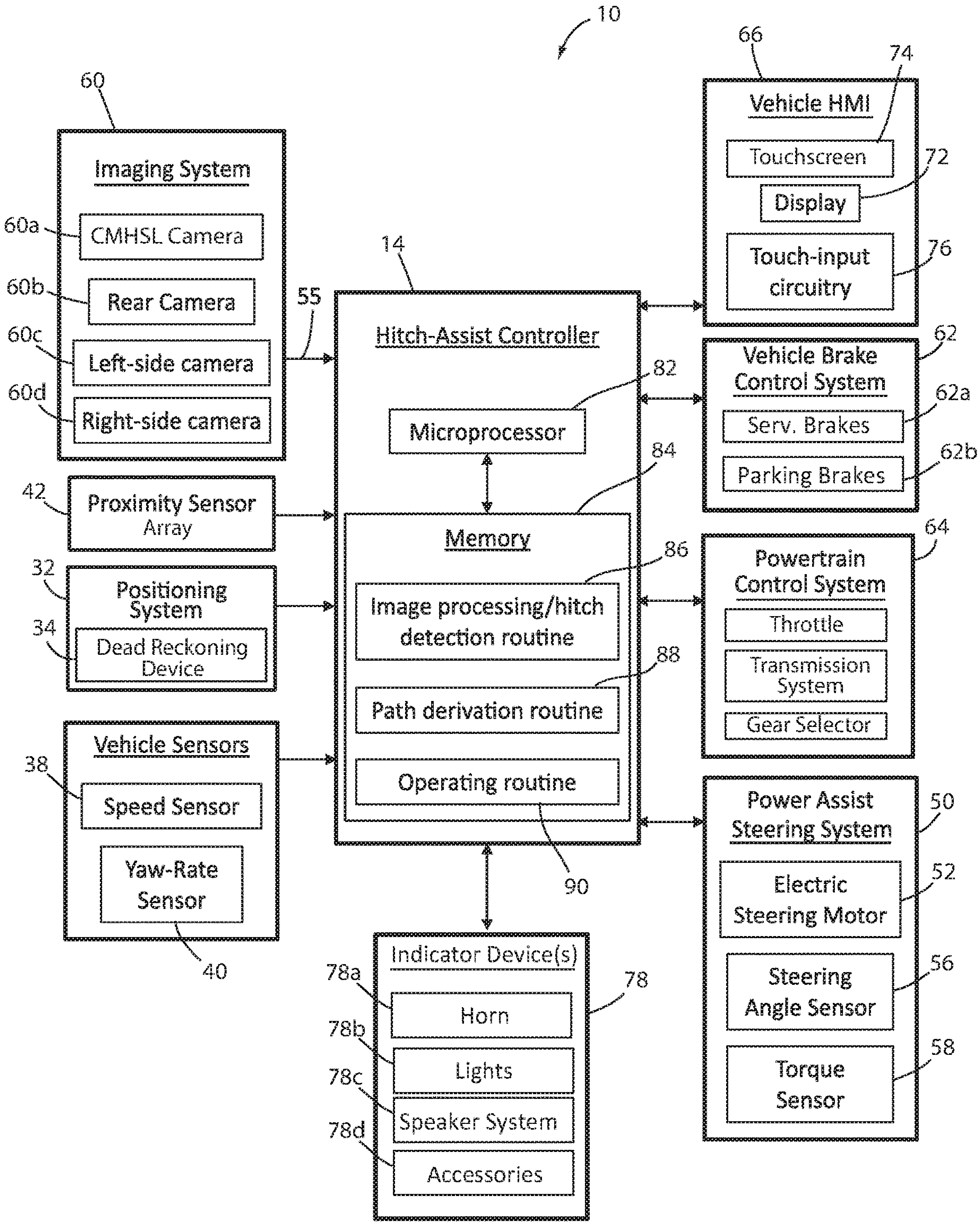

10
66
74
Vehicle HMI
Touchscreen
72
Display
76
Touch-input circuitry
60
Imaging System
60a
CMHSL Camera
60b
Rear Camera
60c
Left-side camera
60d
Right-side camera
14
55
Hitch-Assist Controller
82
Microprocessor
62
Vehicle Brake Control System
62a
Serv. Brakes
62b
Parking Brakes
84
42
Proximity Sensor Array
Memory
86
32
Positioning System
34
Dead Reckoning Device
Image processing/hitch detection routine
64
Powertrain Control System
Throttle
Transmission System
Gear Selector
88
Path derivation routine
Vehicle Sensors
38
Speed Sensor
Yaw-Rate Sensor
40
Operating routine
90
Power Assist Steering System
50
Electric Steering Motor
52
Steering Angle Sensor
56
Torque Sensor
58
Indicator Device(s)
78
78a
Horn
78b
Lights
78c
Speaker System
78d
Accessories

FIG. 2

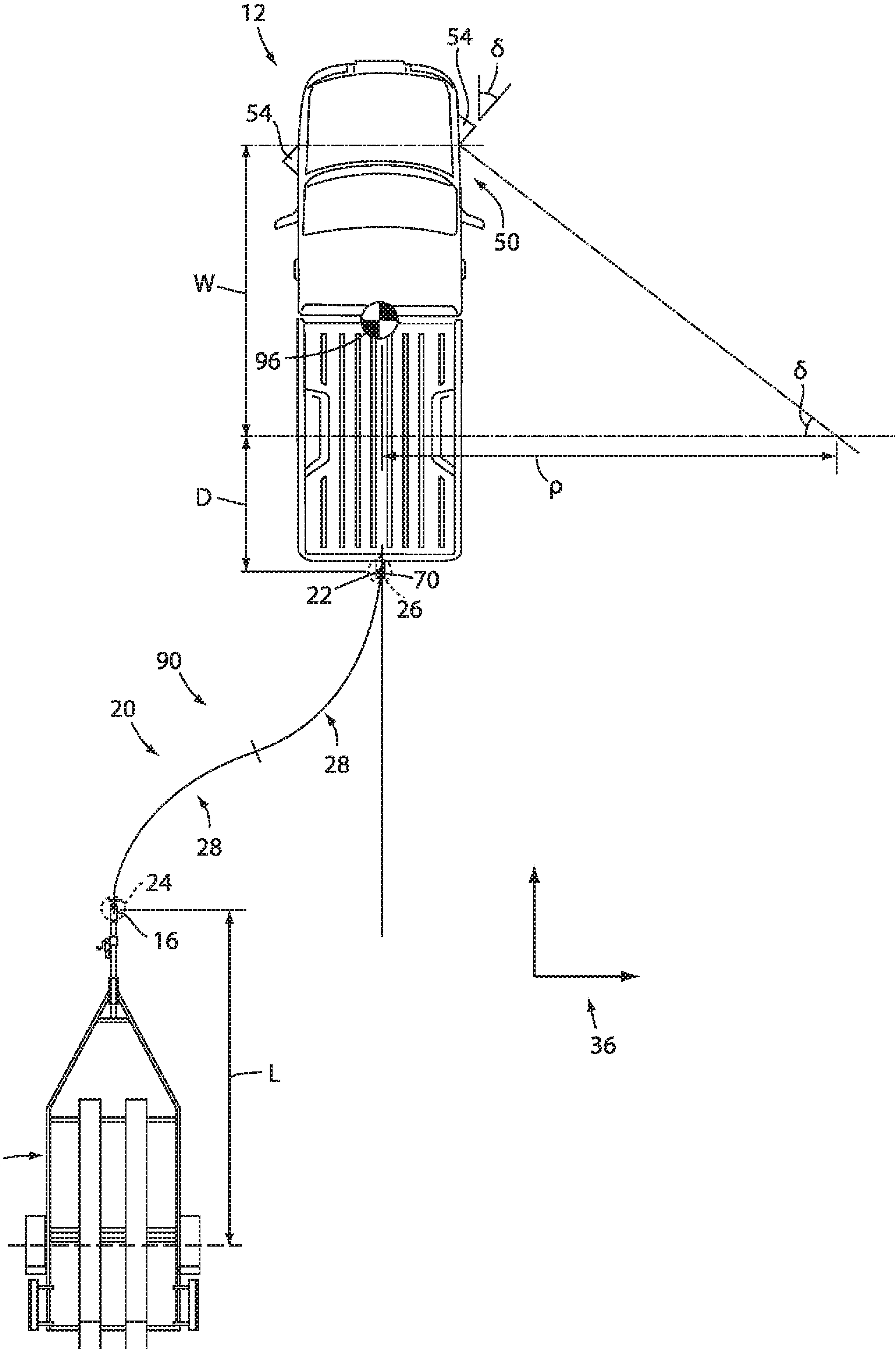


FIG. 3

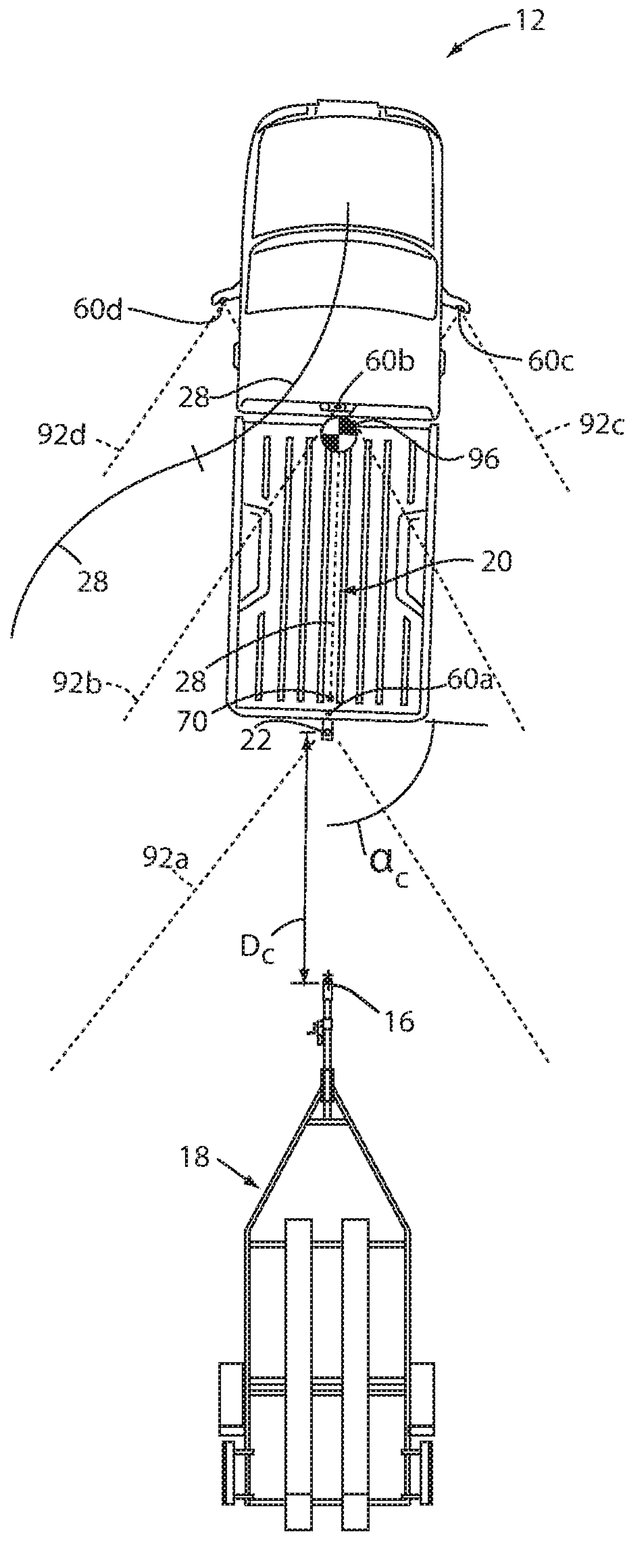

12
60d
60c
60b
28
92d
96
92c
28
20
92b
28
60a
70
22
92a
α_c
D_c
16
18

FIG. 4

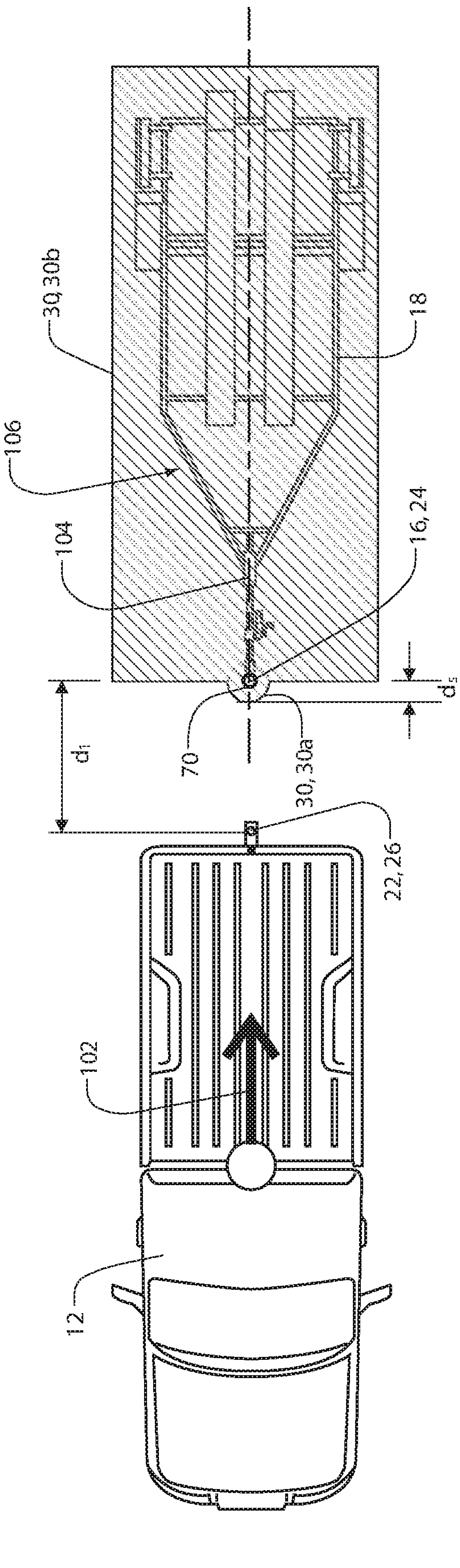

30,30b
18
106
104
16,24
70
30,30a
d_1
d_s
22,26
102
12

FIG. 5A

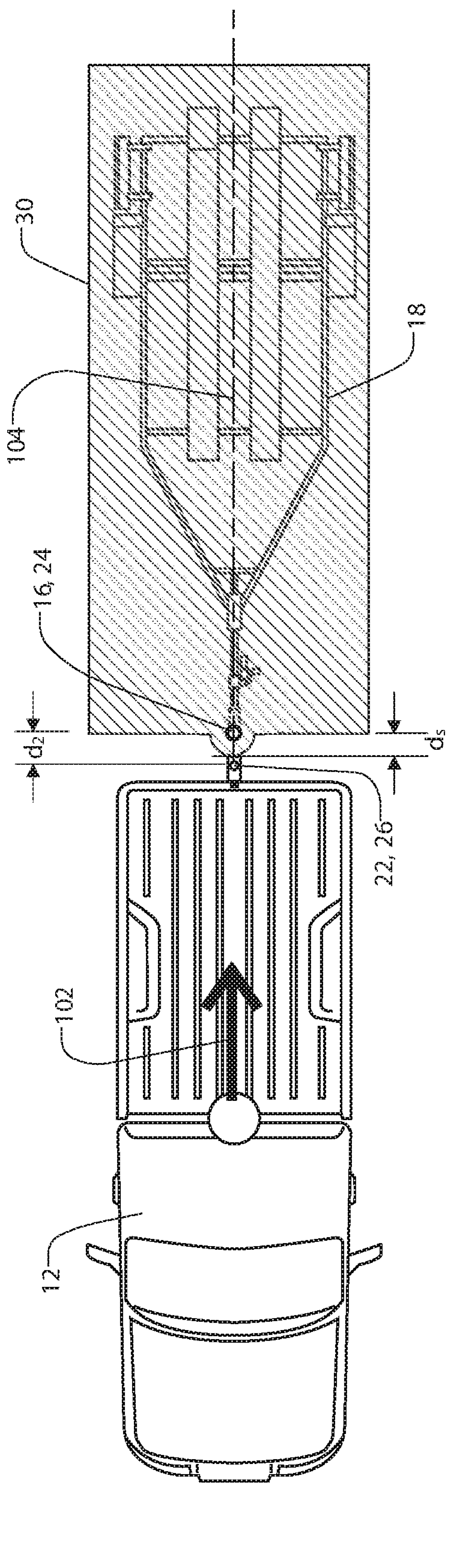

30
18
104
16,24
d_2
d_s
22,26
102
12

FIG. 5B

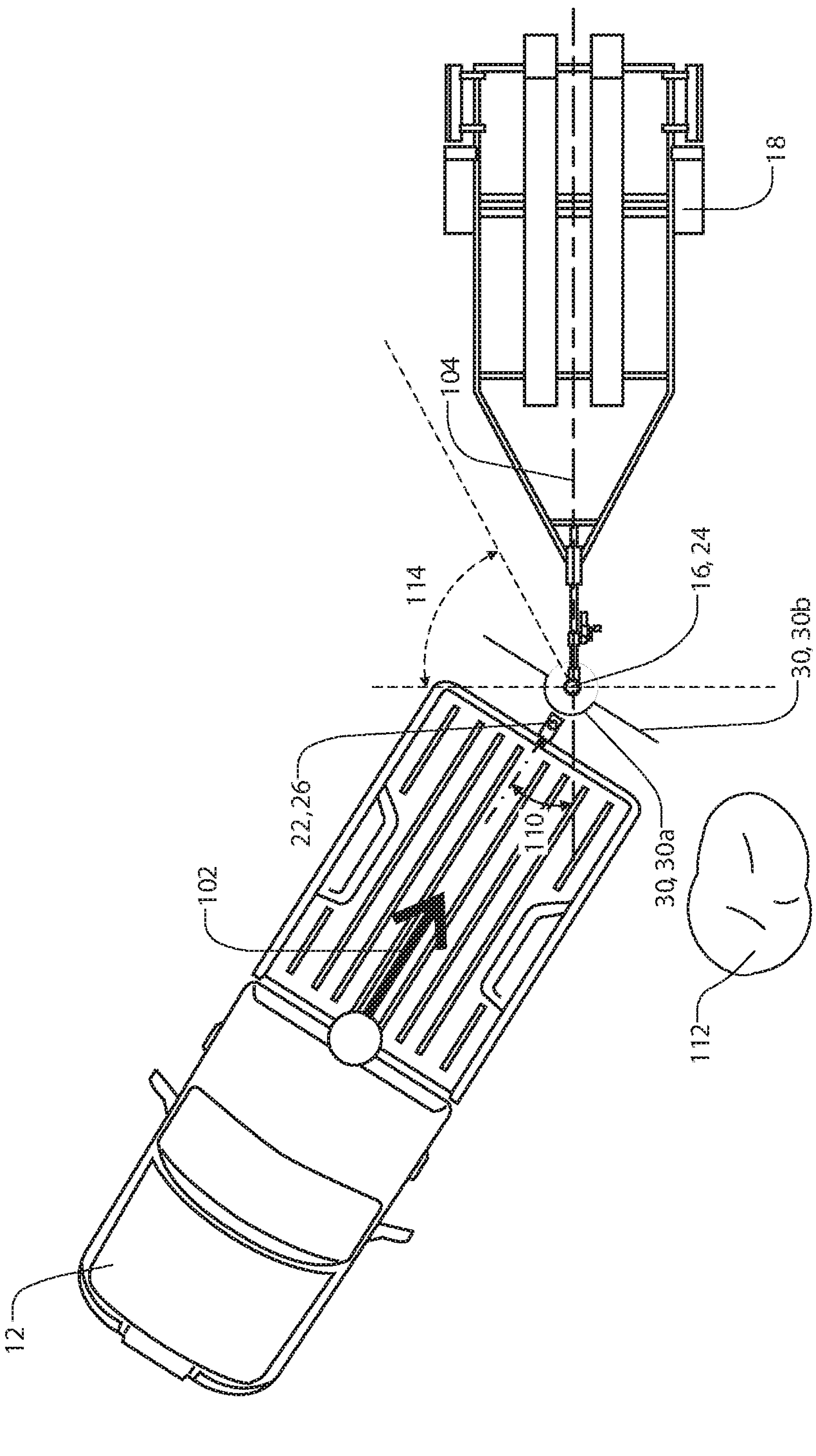


FIG. 6

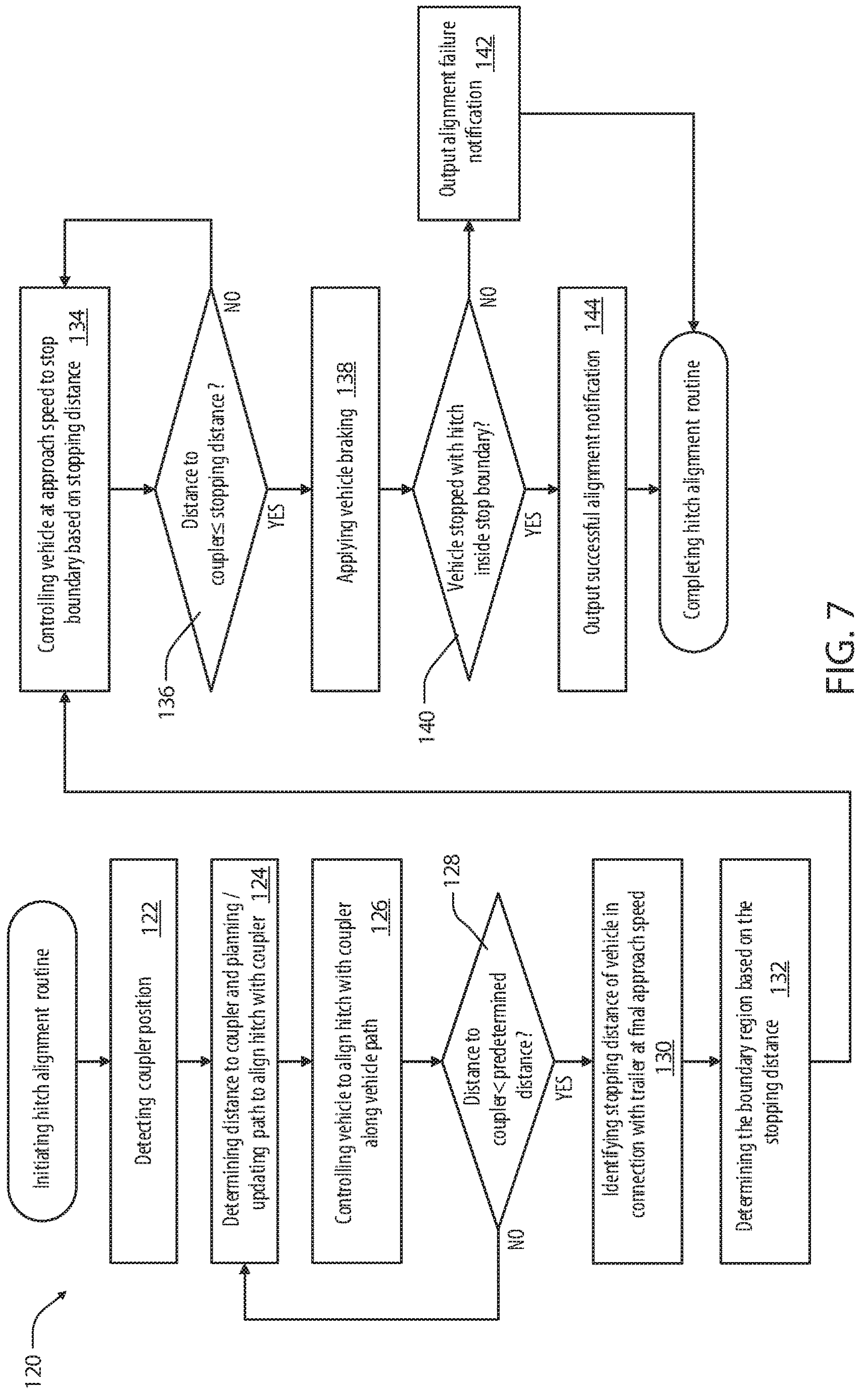

120
Initiating hitch alignment routine
Detecting coupler position 122
Determining distance to coupler and planning / updating path to align hitch with coupler 124
Controlling vehicle to align hitch with coupler along vehicle path 126
128
Distance to coupler < predetermined distance ?
NO
YES
Identifying stopping distance of vehicle in connection with trailer at final approach speed 130
Determining the boundary region based on the stopping distance 132
Controlling vehicle at approach speed to stop boundary based on stopping distance 134
136
Distance to coupler≤ stopping distance ?
NO
YES
Applying vehicle braking 138
140
Vehicle stopped with hitch inside stop boundary?
NO
YES
Output alignment failure notification 142
Output successful alignment notification 144
Completing hitch alignment routine

FIG. 7

SYSTEM AND METHODS FOR VEHICLE ALIGNMENT CONTROL

FIELD OF THE DISCLOSURE

The present disclosure generally relates to a system for assisting in a vehicle-trailer hitching operation. In particular, the present disclosure relates to a system for controlling an alignment between a vehicle and a coupler of a trailer.

BACKGROUND OF THE DISCLOSURE

Hitching a trailer to a vehicle can be a difficult and time-consuming experience. In particular, aligning a vehicle hitch ball with the desired trailer hitch can, depending on the initial location of the trailer relative to the vehicle, require repeated forward and reverse driving coordinated with multiple steering maneuvers to appropriately position the vehicle. Further, through a significant portion of the driving needed for appropriate hitch ball alignment, the trailer hitch cannot be seen, and the hitch ball can, under ordinary circumstances, never actually be seen by the driver. This lack of sight lines requires an inference of the positioning of the hitch ball and hitch based on experience with a particular vehicle and trailer, and can still require multiple instances of stopping and stepping out of the vehicle to confirm alignment or to note an appropriate correction for a subsequent set of maneuvers. Even further, the closeness of the hitch ball to the rear bumper of the vehicle means that any overshoot can cause a collision of the vehicle with the trailer. Accordingly, further advancements may be desired.

SUMMARY OF THE DISCLOSURE

According to one aspect of the present disclosure, a vehicle system is disclosed. The system comprises a hitch mounted on a vehicle and a controller configured to control a trailer alignment routine. The controller is configured to identify a coupler position of a trailer and control motion of the vehicle toward an aligned position. The controller is further configured to calculate a stopping threshold relative to the coupler position. The stopping threshold comprises a semicircle concentric to the coupler position. The controller is further configured to control a braking procedure in response to the hitch passing the stopping threshold.

Embodiments of the first aspect of the disclosure can include any one or a combination of the following features:

- the stopping threshold is identified based on a stopping distance of the vehicle;
- the stopping distance defines a radius of the semicircle relative to the coupler position;
- the motion of the vehicle is controlled along a heading direction;
- the stopping threshold comprises a boundary extending from the semicircle extending around a perimeter of the trailer;
- the boundary extends substantially perpendicular to the heading direction through the coupler position;
- the controller is further configured to compare a hitch location of the hitch to an alignment region extending about the coupler in response to the vehicle stopping, and, based on the comparison, identify if the hitch location is within the alignment region;
- the controller is further configured to output the misalignment signal in response to the hitch location being outside the alignment region;
- the stopping distance of the vehicle is calculated based on a velocity of the vehicle;
- a level detection device, wherein the level detection device comprises at least one of an inertial measurement unit, a gyroscope, an inclinometer, and an accelerometer;
- the controller is further configured to calculate the stopping distance in response to a gradient of a ground surface on which the vehicle is operating identified by the level detection device; and/or
- a weight sensor, wherein the controller is further configured to detect the stopping distance of the vehicle based on a mass of the vehicle.

According to another aspect of the present disclosure, a method for controlling a vehicle is disclosed. The method comprises identifying a coupler position of a trailer in the sensor data and controlling motion of the vehicle to an aligned position aligning a hitch ball of the vehicle with the coupler position. The method further comprises calculating a stopping threshold relative to the coupler position. The stopping threshold comprises a coupler boundary extending around the coupler position. The method further comprises controlling a braking procedure in response to the hitch entering the coupler boundary.

Embodiments of the next aspect of the disclosure can include any one or a combination of the following features:

- identifying the stopping threshold based on a stopping distance of the vehicle;
- the coupler boundary comprises a semicircle extending at the stopping distance about the coupler position;
- calculating a trailer boundary based on a heading direction of the vehicle, wherein the trailer boundary extends from the coupler boundary;
- wherein controlling the braking procedure further comprises controlling the braking procedure in response to the hitch entering the trailer boundary; and/or
- wherein the trailer boundary is calculated to extend substantially perpendicular to a heading direction of the vehicle through the coupler position.

According to another aspect of the present disclosure, a vehicle system configured to control a trailer alignment routine is disclosed. The system comprises a hitch mounted on a vehicle and a sensor configured to capture sensor data in a region proximate to the vehicle. A controller is configured to identify a coupler position of a trailer in the sensor data. The controller is further configured to control the motion of the vehicle along a vehicle heading to an aligned position, wherein the hitch is aligned with the coupler. The controller is further configured to calculate a stopping boundary around at least a portion of the trailer. The stopping boundary comprises a coupler boundary extending at a stopping distance from the coupler and a trailer boundary extending substantially perpendicular to the vehicle heading through the coupler position. In response to the hitch entering the stopping boundary, the controller may control a braking procedure of the vehicle.

These and other aspects, objects, and features of the present disclosure will be understood and appreciated by those skilled in the art upon studying the following specification, claims, and appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. **1** is a perspective view of a vehicle in an unhitched position relative to a trailer;

FIG. 2 is a diagram of a system according to an aspect of the disclosure for assisting in aligning the vehicle with a trailer in a position for hitching the trailer to the vehicle;

FIG. 3 is a plan view of a vehicle during a step of the alignment sequence with the trailer;

FIG. 4 is a plan view of a vehicle controlling the alignment sequence with the trailer;

FIG. 5A is a plan view of a vehicle approaching a trailer during an alignment procedure;

FIG. 5B is a plan view of a vehicle approaching a trailer during an alignment procedure;

FIG. 6 is a plan view of a vehicle approaching a trailer during an alignment procedure demonstrating an obstruction; and

FIG. 7 is a flow chart demonstrating a method for controlling an alignment between a vehicle hitch and a coupler of a trailer in accordance with the disclosure.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

For purposes of description herein, the terms "upper," "lower," "right," "left," "rear," "front," "vertical," "horizontal," "interior," "exterior," and derivatives thereof shall relate to the device as oriented in FIG. **1**. However, it is to be understood that the device may assume various alternative orientations, except where expressly specified to the contrary. It is also to be understood that the specific devices and processes illustrated in the attached drawing, and described in the following specification are simply exemplary embodiments of the inventive concepts defined in the appended claims. Hence, specific dimensions and other physical characteristics relating to the embodiments disclosed herein are not to be considered as limiting, unless the claims expressly state otherwise. Additionally, unless otherwise specified, it is to be understood that discussion of a particular feature or component extending in or along a given direction or the like does not mean that the feature or component follows a straight line or axis in such a direction or that it only extends in such direction or on such a plane without other directional components or deviations, unless otherwise specified.

Referring generally to FIGS. **1-4**, reference numeral **10** designates a hitch assistance system (also referred to as a "hitch assist" system) for a vehicle **12**. In various embodiments, hitch assist system **10** includes a controller **14** configured to acquire position data of a coupler **16** of a trailer **18**. The controller **14** may be configured to derive a vehicle path **20** to align a hitch ball **22** of the vehicle **12** with the coupler **16**. Deriving the vehicle path **20** may include a variety of steps including detecting and compensating for a change in a coupler position **24** in order to control the vehicle **12** to locate a hitch position **26** aligned with the coupler **16**. The vehicle path **20** may comprise a plurality of segments **28**, which may correspond to changes in the operating direction or steering direction of the vehicle **12**. In various embodiments, deriving the vehicle path **20** may include navigating around intervening objects or structures, operating over uneven terrain, following a desired path indicated by an operator or user U, etc. Accordingly, the disclosure may provide for the hitch assist system **10** to provide for improved navigation of the vehicle **12** and/or interaction with the coupler **16** such that trailer **18** may be effectively connected to the vehicle **12** without complication.

In some embodiments, the system **10** may be configured to identify a stopping threshold based on the position data, which may be derived from one or more sensors in communication with the controller **14**. As further discussed in reference to FIGS. **5-7**, the stopping threshold may be demonstrated as a boundary region **30**. In operation, the controller **14** may be configured to process the positional data or scanning data to define the boundary region **30** extending from various portions of the trailer **18** that may be detected in the scanning data as further discussed herein. The extents or distance that the boundary region **30** is defined relative to the trailer **18** and the coupler **16** may be determined by the controller **14** based on a stopping distance of the vehicle **12**. In this configuration, the system **10** may be configured to maneuver the vehicle **12** and control a braking procedure of the vehicle **12** in response to the hitch ball **22** entering the boundary region **30**. In this way, the system **10** may be configured to accurately stop the vehicle **12** such that the hitch ball **22** is aligned with the coupler **16**.

With respect to the general operation of the hitch assist system **10**, as illustrated in the system diagram of FIGS. **2-4**, the system **10** includes various sensors and devices that obtain or otherwise provide vehicle status-related information. This information includes positioning information from a positioning system **32**, which may include a dead reckoning device **34** or, in addition or as an alternative, a global positioning system (GPS), to determine a coordinate location of the vehicle **12** based on the one or more locations of the devices within the positioning system **32**. In particular, the dead reckoning device **34** can establish and track the coordinate location of the vehicle **12** within a localized coordinate system **36** based at least on vehicle speed and steering angle δ as shown in FIG. **3**. Other vehicle information received by hitch assist system **10** may include a speed of the vehicle **12** from a speed sensor **38** and a yaw rate of the vehicle **12** from a yaw rate sensor **40**. It is contemplated that in additional embodiments, a proximity sensor **42** or an array thereof, and other vehicle sensors and devices may provide sensor signals or other information, such as sequential images of the trailer **18**, including the detected coupler **16**, that the controller **14** of the hitch assist system **10** may process with various routines to determine the height H and position (e.g., based on the distance D_c and angle α_c) of coupler **16**.

As further shown in FIG. **2**, one embodiment of the hitch assist system **10** is in communication with the steering system **50** of vehicle **12**. The steering system **50** may be a power assist steering system **50** including a steering motor **52** to operate the steered wheels **54** (FIG. **1**) of the vehicle **12** for moving the vehicle **12** in such a manner that the vehicle yaw changes with the vehicle velocity and the steering angle δ. In the illustrated embodiment, the power assist steering system **50** is an electric power-assisted steering ("EPAS") system including electric steering motor **52** for turning the steered wheels **54** to a steering angle δ based on a steering command, whereby the steering angle δ may be sensed by a steering angle sensor **56** of the power assist steering system **50**. The steering command may be provided by the hitch assist system **10** for autonomously steering during a trailer hitch alignment maneuver and may alternatively be provided manually via a rotational position (e.g., steering wheel angle) of a steering wheel of vehicle **12**.

In the illustrated embodiment, the steering wheel of the vehicle **12** is mechanically coupled with the steered wheels **54** of the vehicle **12**, such that the steering wheel moves in concert with steered wheels **54**, preventing manual intervention with the steering wheel during autonomous steering. More specifically, a torque sensor **58** is provided on the power assist steering system **50** that senses torque on the steering wheel that is not expected from autonomous control of the steering wheel and therefore indicative of manual intervention. In this configuration, the hitch assist system **10** may alert the driver to discontinue manual intervention with the steering wheel and/or discontinue autonomous steering. In alternative embodiments, some vehicles have a power assist steering system **50** that allows a steering wheel to be partially decoupled from movement of the steered wheels **54** of such a vehicle.

With continued reference to FIG. **2**, the power assist steering system **50** provides the controller **14** of the hitch assist system **10** with information relating to a rotational position of steered wheels **54** of the vehicle **12**, including a steering angle δ. The controller **14** in the illustrated embodiment processes the current steering angle, in addition to various vehicle **12** conditions to guide the vehicle **12** along the desired path **20** (FIG. **3**). It is conceivable that the hitch assist system **10**, in additional embodiments, may be an integrated component of the power assist steering system **50**. For example, the power assist steering system **50** may include a hitch assist algorithm for generating vehicle steering information and commands as a function of all or a portion of information received from an imaging system **60**, the power assist steering system **50**, a vehicle brake control system **62**, a powertrain control system **64**, and other vehicle sensors and devices, as well as a human-machine interface ("HMI") **66**, as discussed further below.

As also illustrated in FIG. **2**, the vehicle brake control system **62** may also communicate with the controller **14** to provide the hitch assist system **10** with braking information, such as vehicle wheel speed, and to receive braking commands from the controller **14**. The brake control system **62** may be configured to control service brakes **62***a* and a parking brake **62***b*. The parking brake **62***b* may correspond to an electronic parking brake system that may be in communication with the controller **14**. Accordingly, in operation, the controller **14** may be configured to control the brakes **62***a* and **62***b* as well as detect vehicle speed information, which may be determined from individual wheel speed sensors monitored by the brake control system **62**. Vehicle speed may also be determined from the powertrain control system **64**, the speed sensor **38**, and/or the positioning system **32**, among other conceivable means. In some embodiments, individual wheel speeds can also be used to determine a vehicle yaw rate, which can be provided to the hitch assist system **10** in the alternative or in addition to the vehicle yaw rate sensor **40**.

The hitch assist system **10** can further provide vehicle braking information to the brake control system **62** for allowing the hitch assist system **10** to control braking of the vehicle **12** during backing of the trailer **18**. For example, the hitch assist system **10**, in some embodiments, may regulate speed of the vehicle **12** during alignment of the vehicle **12** with the coupler **16** of trailer **18**, which can reduce the potential for a collision with trailer **18**, and can bring vehicle **12** to a complete stop at a determined endpoint **70** of the path **20**. It is disclosed herein that the hitch assist system **10** can additionally or alternatively issue an alert signal corresponding to a notification of an actual, impending, and/or anticipated collision with a portion of trailer **18**. As mentioned above, regulation of the speed of the vehicle **12** may be advantageous to prevent collision with trailer **18**.

In some embodiments, the powertrain control system **64**, as shown in the embodiment illustrated in FIG. **2**, may also interact with the hitch assist system **10** for regulating speed and acceleration of the vehicle **12** during partial or autonomous alignment with trailer **18**. During autonomous operation, the powertrain control system **64** may further be utilized and configured to control a throttle as well as a drive gear selection of a transmission of the vehicle **12**. Accordingly, in some embodiments, the controller **14** may be configured to control a gear of the transmission system and/or prompt the user U to shift to a desired gear to complete semi-automated operations of the vehicle **12**.

As previously discussed, the hitch assist system **10** may communicate with human-machine interface ("HMI") **66** of the vehicle **12**. The HMI **66** may include a vehicle display **72**, such as a center-stack mounted navigation or entertainment display (FIG. **1**). HMI **66** further includes an input device, which can be implemented by configuring display **72** as a portion of a touchscreen **74** with circuitry **76** to receive an input corresponding with a location over display **72**. Other forms of input, including one or more joysticks, digital input pads, or the like, can be used in place or in addition to touchscreen **74**. Further, the hitch assist system **10** may communicate via wireless communication with another embodiment of the HMI **66**, such as with one or more handheld or portable devices **80** (FIG. **1**), including one or more smartphones. The portable device **80** may also include the display **72** for displaying one or more images and other information to a user U. For instance, the portable device **80** may display one or more images of the trailer **18** on the display **72** and may be further configured to receive remote user inputs via touchscreen circuitry **76**. In addition, the portable device **80** may provide feedback information, such as visual, audible, and tactile alerts.

In some embodiments, the hitch assist system **10** may further be in communication with one or more indicator devices **78**. The indicator devices **78** may correspond to conventional vehicle indicators, such as a vehicle horn **78***a*, lights **78***b*, a speaker system **78***c*, vehicle accessories **78***d*, etc. In some embodiments, the indicator devices **78** may further include one or more accessories **78***d*, which may correspond to communication devices, remote controls, and a variety of devices that may provide for status and operational feedback between the user U and the vehicle **12**. For example, in some embodiments, the HMI **66**, the display **72**, and the touchscreen **74** may be controlled by the controller **14** to provide status updates identifying the operation or receiving instructions or feedback to control the hitch assist system **10**. Additionally, in some embodiments, the portable device **80** may be in communication with the controller **14** and configured to display or otherwise indicate one or more alerts or messages related to the operation of the hitch assist system **10**.

Still referring to the embodiment shown in FIG. **2**, the controller **14** is configured with a microprocessor **82** to process logic and routines stored in memory **84** that receive information from the above-described sensors and vehicle systems, including the imaging system **60**, the power assist steering system **50**, the vehicle brake control system **62**, the powertrain control system **64**, and other vehicle sensors and devices. The controller **14** may generate vehicle steering information and commands as a function of all or a portion of the information received. Thereafter, the vehicle steering information and commands may be provided to the power assist steering system **50** for affecting the steering of the vehicle **12** to achieve a commanded path **20** (FIG. **3**) of travel for alignment with the coupler **16** of trailer **18**. The controller **14** may include the microprocessor **82** and/or other analog and/or digital circuitry for processing one or more routines. Also, the controller **14** may include the memory **84** for storing one or more routines, including an image processing routine **86** and/or hitch detection routine, a path derivation routine **88**, and an operating routine **90**.

It should be appreciated that the controller **14** may be a stand-alone dedicated controller or may be a shared controller integrated with other control functions, such as integrated with a vehicle sensor system, the power assist steering system **50**, and other conceivable onboard or off-board vehicle control systems. It should further be appreciated that the image processing routine **86** may be carried out by a dedicated processor, for example, within a stand-alone imaging system for vehicle **12** that can output the results of its image processing to other components and systems of vehicle **12**, including microprocessor **82**. Further, any system, computer, processor, or the like, that completes image processing functionality, such as that described herein, may be referred to herein as an "image processor" regardless of other functionality it may also implement (including simultaneously with executing image processing routine **86**).

System **10** may also incorporate the imaging system **60** that includes one or more exterior cameras. Examples of exterior cameras are illustrated in FIG. **4** and include rear camera **60***a*, center high-mount stop light (CHMSL) camera **60***b*, and side-view cameras **60***c* and **60***d*, although other arrangements including additional or alternative cameras are possible. In one example, imaging system **60** can include rear camera **60***a* alone or can be configured such that system **10** utilizes only rear camera **60***a* in a vehicle with multiple exterior cameras. In another example, the various cameras **60***a*-**60***d* included in imaging system **60** can be positioned to generally overlap in their respective fields of view, which in the depicted arrangement include fields of view **92***a*, **92***b*, **92***c*, and **92***d* to correspond with rear camera **60***a*, center high-mount stop light (CHMSL) camera **60***b*, and side-view cameras **60***c* and **60***d*, respectively. In this manner, image data from two or more of the cameras can be combined in image processing routine **86**, or in another dedicated image processor within imaging system **60**, into a single image.

As an example of combining image data from multiple cameras, the image data can be used to derive stereoscopic image data that can be used to reconstruct a three-dimensional scene of the area or areas within overlapped areas of the various fields of view **92***a*, **92***b*, **92***c*, and **92***d*, including any objects (obstacles or coupler **16**, for example) therein. In an embodiment, the use of two images including the same object can be used to determine a location of the object relative to the two image sources, given a known spatial relationship between the image sources. In this respect, the image processing routine **86** can use known programming and/or functionality to identify an object within image data from the various cameras **60***a*, **60***b*, **60***c*, and **60***d* within imaging system **60**. In either example, the image processing routine **86** can include information related to the positioning of any cameras **60***a*, **60***b*, **60***c*, and **60***d* present on vehicle **12** or utilized by system **10**, including relative to a center **96** (FIG. **1**) of vehicle **12**, for example, such that the positions of cameras **60***a*, **60***b*, **60***c*, and **60***d* relative to center **96** and/or to each other can be used for object positioning calculations and to result in object position data relative to the center **96** of vehicle **12**, for example, or other features of vehicle **12**, such as hitch ball **22** (FIG. **1**), with known positions relative to center **96** of the vehicle **12**.

The image processing routine **86** can be specifically programmed or otherwise configured to locate coupler **16** within image data. In one example, the image processing routine **86** can identify the coupler **16** within the image data based on stored or otherwise known visual characteristics of coupler **16** or hitches in general. In another embodiment, a marker in the form of a sticker, or the like, may be affixed with trailer **18** in a specified position relative to coupler **16** in a manner similar to that which is described in commonly-assigned U.S. Pat. No. 9,102,271, the entire disclosure of which is incorporated by reference herein. In such an embodiment, the image processing routine **86** may be programmed with identifying characteristics of the marker for location in image data, as well as the positioning of coupler **16** relative to such a marker so that the position **24** of the coupler **16** can be determined based on the marker location.

Additionally or alternatively, controller **14** may seek confirmation of the determined coupler **16**, via a prompt on touchscreen **74**. If the coupler **16** determination is not confirmed, further image processing may be provided, or user-adjustment of the position **24** of coupler **16** may be facilitated, either using touchscreen **74** or another input to allow the user U to move the depicted position **24** of coupler **16** on touchscreen **74**, which controller **14** uses to adjust the determination of position **24** of coupler **16** with respect to vehicle **12** based on the above-described use of image data. Alternatively, the user U can visually determine the position **24** of coupler **16** within an image presented on HMI **66** and can provide a touch input in a manner similar to that which is described in co-pending, commonly-assigned U.S. Pat. No. 10,266,023, the entire disclosure of which is incorporated by reference herein. The image processing routine **86** can then correlate the location of the touch input with the coordinate system **36** applied to image data shown on the display **72**, which may be depicted as shown in FIG. **3**.

As shown in FIG. **3**, the image processing routine **86** and operating routine **90** may be used in conjunction with each other to determine the path **20** along which hitch assist system **10** can guide vehicle **12** to align hitch ball **22** and coupler **16** of trailer **18**. In the example shown, an initial position of vehicle **12** relative to trailer **18** may be such that coupler **16** is only in the field of view **92***c* of side camera **60***c*, with vehicle **12** being positioned laterally from trailer **18** but with coupler **16** being almost longitudinally aligned with hitch ball **22**. In this manner, upon initiation of hitch assist system **10**, such as by user input on touchscreen **74**, for example, image processing routine **86** can identify coupler **16** within the image data of camera **60***c* and estimate the position **24** of coupler **16** relative to hitch ball **22**. The position **24** of the coupler **16** may be identified by the system **10** using the image data in accordance by receiving focal length information within image data to determine a distance D_c to coupler **16** and an angle α_c of offset between coupler **16** and the longitudinal axis of vehicle **12**. This information may also be used in light of the position **24** of coupler **16** within the field of view of the image data to determine or estimate the height H_c of coupler **16**. Once the positioning D_c, α_c of coupler **16** has been determined and, optionally, confirmed by the user U, the controller **14** can take control of at least the vehicle steering system **50** to control the movement of vehicle **12** along the desired path **20** to align the hitch ball position **26** of the vehicle hitch ball **22** with coupler **16**.

Continuing with reference to FIGS. **3** and **4** with additional reference to FIG. **2**, controller **14**, having estimated the positioning D_c, α_c of coupler **16**, as discussed above, can, in one example, execute path derivation routine **88** to determine vehicle path **20** to align the vehicle hitch ball **22** with coupler **16**. In particular, controller **14** can have stored in memory **84** various characteristics of vehicle **12**, including the wheelbase W, the distance from the rear axle to the hitch ball **22**, which is referred to herein as the drawbar length L, as well as the maximum angle to which the steered wheels **54** can be turned δ_{max}. As shown, the wheelbase W and the current steering angle δ can be used to determine a corresponding turning radius ρ for vehicle **12** according to the equation:

$$\rho = \frac{1}{W \tan \delta} \quad (1)$$

in which the wheelbase W is fixed and the steering angle δ can be controlled by controller **14** by communication with the steering system **50**, as discussed above. In this manner, when the maximum steering angle δ_{max} is known, the smallest possible value for the turning radius ρ_{min} is determined as:

$$\rho_{min} = \frac{1}{W \tan \delta_{max}} \quad (2)$$

Path derivation routine **88** can be programmed to derive vehicle path **20** to align a known location of the vehicle hitch ball **22** with the estimated position **24** of coupler **16** that takes into account the determined minimum turning radius ρ_{min} to allow path **20** to use the minimum amount of space and maneuvers. In this manner, path derivation routine **88** can use the position of vehicle **12**, which can be based on the center **96** of vehicle **12**, a location along the rear axle, the location of the dead reckoning device **34**, or another known location on the coordinate system **36**, to determine both a lateral distance to the coupler **16** and a forward or rearward distance to coupler **16** and derive a path **20** that achieves the needed lateral and forward-backward movement of vehicle **12** within the limitations of steering system **50**. The derivation of path **20** further takes into account the positioning of hitch ball **22**, based on length L, relative to the tracked location of vehicle **12** (which may correspond with the center **96** of mass of vehicle **12**, the location of a GPS receiver, or another specified, known area) to determine the needed positioning of vehicle **12** to align hitch ball **22** with coupler **16**.

Referring now to FIGS. **5**A and **5**B, top plan views of the vehicle **12** are shown demonstrating a guidance routine configured to align the hitch ball **22** with coupler **16**. As illustrated, the controller **14** may be configured to maneuver the vehicle **12** in reverse along a heading direction **102**, which may be identified based on the path **20** determined via the path derivation routine **88**. As previously discussed, the controller **14** may be configured to control the brake control system **62** to control the approach of the vehicle **12** at the endpoint **70** of the path **20**. In order to ensure that the vehicle **12** is accurately stopped at the endpoint **70**, the controller **14** may further determine the boundary region **30** based on the stopping distance of the vehicle **12**. In this way, the system **10** may control the vehicle **12** to accurately align the hitch ball **22** with the coupler **16** in a variety of approach angles while preventing a collision between the vehicle **12** and the trailer **18**.

In FIG. **5**A, the vehicle **12** is shown at a first distance d_1, and, in FIG. **5**B, the vehicle **12** is shown at a second distance d_2 relative to the coupler position **24**. As the vehicle **12** approaches the trailer **18**, the controller **14** may decrease the vehicle speed to an approach speed. The approach speed of the vehicle **12** may provide for a stopping distance d_s of the vehicle to be consistently controlled by the system. For example, the stopping distance d_s of the vehicle **12** may be calculated based on various control parameters of the brake control system **62** and/or calibrated by sample data captured by the system **10** during one or more trial measurements. The calculation of the stopping distance d_s may be calculated as a function of the velocity of the vehicle **12**, the performance of the brake system **62**, a surface gradient or angle of the surface on which the vehicle **12** is operating and the mass of the vehicle **12**. In order to provide for the surface gradient, the controller **14** may be in communication with an inertial measurement unit (IMU), a gyroscope, an inclinometer, and/or an accelerometer. Additionally, the mass of the vehicle **12** may be measured by one or more weight sensors or pressure sensors in communication with the controller **14**. In this way, the system **10** may be configured to calculate and/or determine the stopping distance d_s.

In some embodiments, the stopping distance d_s may be calibrated based on a desired deceleration rate of the vehicle **12**. The calibration may be based on the surface gradient, the mass of the vehicle **12**, etc. as previously discussed. Additionally, the stopping distance d_s may be adjusted and calibrated to suit a comfort condition or desired time required to complete an alignment routine. For example, an increased deceleration rate may reduce comfort, but may improve a time necessary to complete the alignment routine by allowing for increased operating speeds and/or a reduced stopping distance d_s. In contrast, a low deceleration rate may result in a smoother stoppage of the vehicle **12** but may ether increase an alignment time or increase the stopping distance d_s. Accordingly, the operation of the system **10** may be calibrated to suit a desired rate of deceleration and additional variable that may be associated with the rate of deceleration as discussed herein.

Based on the stopping distance d_s, the controller **14** may calculate the boundary region **30** extending from a perimeter **106** of the trailer **18**. The perimeter **106** of the trailer **18** may be detected in the scanning data as a perimeter edge of the trailer **18** is identified in image data and/or proximity data captured by the imaging system **60** or various additional scanning devices (e.g. ultrasonic sensors, radar sensors, etc.). In some embodiments, the controller **14** may calculate a coupler boundary **30***a* based on the perimeter **106** of the coupler **16**. The coupler boundary **30***a* which may correspond to a semicircle positioned concentrically about the coupler position **24**. Additionally, the boundary region **30** may comprise a trailer boundary **30***b*, which may extend substantially perpendicular to the heading direction **102** through the coupler position **24**. In this way, the boundary region **30** may vary based on an approach angle between the heading direction **102** of the vehicle **12** and a coupler trajectory **104**, which may be substantially aligned with a centerline C of the trailer **18**. The adjustment of the boundary region **30** is further discussed in reference to FIG. **6**.

Referring still to FIGS. **5**A and **5**B, in response to a portion of the vehicle **12** entering or crossing a threshold of the boundary region **30**, the controller **14** may control the brake system **62** to stop the vehicle **12**. As shown in FIG. **5**B, the controller **14** may activate the braking routine in response to the hitch ball **22** entering the boundary region **30** such that the vehicle **12** is accurately stopped with that the hitch ball **22** is aligned with the coupler **16**. In order to provide for the alignment as shown in FIGS. **5**A and **5**B, the controller **14** may calculate the path derivation routine **88** such that the heading direction **102** of the vehicle **12** and a coupler trajectory **104** are substantially aligned with a centerline C when the vehicle **12** enters the boundary region **30**.

Referring now to FIG. **6**, the vehicle **12** is shown approaching the trailer **18** along an approach angle **110**.

Though in many cases, aligning the heading direction **102** with the coupler trajectory **104** as shown in FIGS. **5**A and **5**B may be favorable, in many situations, the alignment of the approach angle **110** may be problematic or impossible. For example, if the system **10** is only configured to operate or maneuver the vehicle **12** in the reverse direction, a requirement of aligning the heading direction **102** with the coupler trajectory **104** may result in limited operating conditions of the system **10** due the navigational limitations related to the dynamics (e.g. minimum turning radius ρ_{min}) of the vehicle **12**. Additionally, in some scenarios, the alignment of the heading direction **102** with the coupler trajectory **104** will be limited due to the presence of one or more objects **112** that may obstruct the path **20** of the vehicle **12**. In such situations, the controller **14** may be configured to maneuver the vehicle **12** such that the approach angle is less than a critical angle **114**, which may be dependent on the dimensions or proportion of the trailer **18**, the coupler **16**, the hitch ball **22** and corresponding hitch mount, etc. The critical angle **114** may be programmed by the user U and or detected from the image data as discussed herein.

In operation, the critical angle **114** may be compared with the boundary region **30** to determine an alignment feasibility of aligning the hitch ball **22** with the coupler **16**. For example, if a portion of the trailer boundary **30***b* or the hitch boundary **30***a* intersect with or cross the critical angle **114**, the controller **14** may cancel an alignment routine. Additionally, if any portion of the vehicle **12** enters or crosses a threshold of the boundary region **30**, the controller **14** may control the brake system **62** to stop the vehicle **12**. In this way, the controller **14** may be configured to determine the alignment feasibility of the hitch ball **22** with the coupler **16** and trigger a stopping action of the brake system to align the hitch ball **22** with the coupler **16** based on the boundary region **30**. In this way, the disclosure may provide for robust operation of the vehicle **12** to align the hitch ball **22** with the coupler **16** for connection.

Referring now to FIG. **7**, a flow chart demonstrating an alignment routine **120** is shown in accordance with the disclosure. In operation, the controller **14** may begin the routine **120** by detecting the coupler position **24** of the coupler **16** in connection with the trailer **18** (**122**). Once the coupler position **24** is determined, the controller **14** may continue to identify the path **20** of the vehicle **12** based on the path derivation routine **88** (**124**). Once the path is identified, the controller **14** may control the system **10** to maneuver the vehicle **12** along the path **20** (**126**). While maneuvering the vehicle **12**, the controller **14** may monitor the distance of the coupler position **24** along the path **20** (**128**). If the distance is greater than an approach distance (e.g. a predetermined distance), the controller **14** may return to step **124**. If the distance is less than the approach distance, the controller **14** may identify the stopping distance d_s of the vehicle **12** based on the approach speed, load, and additional operating parameters as discussed herein (**130**).

Based on the stopping distance d_s, the controller **14** may further define the boundary region **30** (**132**). Once the boundary region **30** is determined, the controller **14** may continue to maneuver the vehicle **12** along the path **20** at the approach speed (**134**). Additionally, the controller **14** may continue monitoring the distance to the coupler position **24** along the path **20** to determine if a portion (e.g. the hitch ball **22**) of the vehicle **12** has entered or crossed a threshold of the boundary region **30** (**136**). If the vehicle **12** has entered the hitch boundary **30**, the controller **14** may control the brake control system **62** to stop the vehicle **12** (**138**). If the vehicle **12** has not entered the hitch boundary **30**, the controller **14** may continue to control the vehicle **12** along the path **20** at the approach speed (**134**).

After the vehicle **12** has stopped, the controller **14** may determine if the hitch position **26** is aligned with the coupler position **24** (**140**). The determination of the alignment of the hitch position **26** with the coupler position **24** may be determined based on the image data captured via the imaging system **60**. If the hitch position **26** is not aligned with the coupler position **24**, the controller **14** may output an alignment failure indication or notification (**142**). If the hitch position **26** is aligned with the coupler position **24** in step **140**, the controller **14** may output an alignment success indication (**144**). Following either of steps **142** and **144**, the controller **14** may complete the alignment routine **120**. In this way, based on the determination of the boundary region **30**, the controller **14** may accurately stop the vehicle **12** with the hitch ball **22** aligned with the coupler **16**.

The specific detailed steps discussed in reference to the various embodiments and methods described herein are examples provided to demonstrate some useful applications of the systems and devices disclosed by the application. It shall be understood that though specific devices are discussed in reference to the system **10**, various devices that may provide similar operational characteristics may be implemented to provide the methods discussed herein. Accordingly, the detailed embodiments provided herein shall not be considered limiting to the scope of the disclosure.

It is to be understood that variations and modifications can be made on the aforementioned structure without departing from the concepts of the present disclosure, and further it is to be understood that such concepts are intended to be covered by the following claims unless these claims by their language expressly state otherwise.

For purposes of this disclosure, the term "coupled" (in all of its forms, couple, coupling, coupled, etc.) generally means the joining of two components (electrical or mechanical) directly or indirectly to one another. Such joining may be stationary in nature or movable in nature. Such joining may be achieved with the two components (electrical or mechanical) and any additional intermediate members being integrally formed as a single unitary body with one another or with the two components. Such joining may be permanent in nature or may be removable or releasable in nature unless otherwise stated.

It is also important to note that the construction and arrangement of the elements of the disclosure as shown in the exemplary embodiments is illustrative only. Although only a few embodiments of the present innovations have been described in detail in this disclosure, those skilled in the art who review this disclosure will readily appreciate that many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, mounting arrangements, use of materials, colors, orientations, etc.) without materially departing from the novel teachings and advantages of the subject matter recited. For example, elements shown as integrally formed may be constructed of multiple parts or elements shown as multiple parts may be integrally formed, the operation of the interfaces may be reversed or otherwise varied, the length or width of the structures and/or members or connector or other elements of the system may be varied, the nature or number of adjustment positions provided between the elements may be varied. It should be noted that the elements and/or assemblies of the system may be constructed from any of a wide variety of materials that provide sufficient strength or durability, in any of a wide variety of colors, textures, and combinations. Accordingly, all such modifications are intended to be included within the scope of the present innovations. Other substitutions, modifications, changes, and omissions may be made in the design, operating conditions, and arrangement of the desired and other exemplary embodiments without departing from the spirit of the present innovations.

It will be understood that any described processes or steps within described processes may be combined with other disclosed processes or steps to form structures within the scope of the present disclosure. The exemplary structures and processes disclosed herein are for illustrative purposes and are not to be construed as limiting.

What is claimed is:

1. A vehicle system configured to control a trailer alignment routine, comprising:
- a hitch mounted on a vehicle; and
- a controller that:
  - identifies a coupler position of a trailer;
  - controls motion of the vehicle to toward an aligned position;
  - calculates a stopping threshold identified based on a stopping distance of the vehicle relative to the coupler position, wherein the stopping threshold comprises a semicircle concentric to the coupler position and the stopping distance defines a radius of the semicircle relative to the coupler position; and
  - controls a braking procedure in response to the hitch passing the stopping threshold.

2. The system according to claim **1**, wherein the motion of the vehicle is controlled along a heading direction.

3. The system according to claim **2**, wherein the stopping threshold comprises a boundary extending from the semicircle extending around a perimeter of the trailer.

4. The system according to claim **3**, wherein the boundary extends substantially perpendicular to the heading direction through the coupler position.

5. The system according to claim **1**, wherein the controllers further:
- compares a hitch location of the hitch to an alignment region extending about the coupler in response to the vehicle stopping; and
- based on the comparison, identifies if the hitch location is within the alignment region.

6. The system according to claim **5**, wherein the controller further:
- outputs a misalignment signal in response to the hitch location being outside the alignment region.

7. The system according to claim **1**, wherein the stopping distance of the vehicle is calculated based on a velocity of the vehicle.

8. The system according to claim **7**, further comprising a level detection device.

9. The system according to claim **8**, wherein the level detection device comprises at least one of an inertial measurement unit, a gyroscope, an inclinometer, and an accelerometer.

10. The system according to claim **8**, wherein the controller further calculates the stopping distance in response to a gradient of a ground surface on which the vehicle is operating identified by the level detection device.

11. The system according to claim **7**, further comprising a weight sensor, wherein the controller further detects the stopping distance of the vehicle based on a mass of the vehicle.

12. A method for controlling a vehicle comprising:
- identifying a coupler position of a trailer in the sensor data;
- controlling motion of the vehicle to an aligned position aligning a hitch ball of the vehicle with the coupler position;
- calculating a stopping threshold based on a stopping distance of the vehicle relative to the coupler position, wherein the stopping threshold comprises a coupler boundary extending around the coupler position and the coupler boundary comprises a semicircle extending at the stopping distance about the coupler position; and
- controlling a braking procedure in response to the hitch entering the coupler boundary.

13. The method according to **12**, further comprising
- calculating a trailer boundary based on a heading direction of the vehicle, wherein the trailer boundary extends from the coupler boundary.

14. The method according to claim **13**, wherein controlling the braking procedure further comprises controlling the braking procedure in response to the hitch entering the trailer boundary.

15. The method according to claim **13**, wherein the trailer boundary is calculated to extend substantially perpendicular to a heading direction of the vehicle through the coupler position.

16. A vehicle system configured to control a trailer alignment routine, comprising:
- a hitch mounted on a vehicle;
- a sensor configured to capture sensor data in a region proximate to the vehicle; and
- a controller that:
  - identifies a coupler position of a trailer in the sensor data;
  - controls motion of the vehicle along a vehicle heading to an aligned position, wherein the hitch is aligned with the coupler;
  - calculates a stopping boundary around at least a portion of the trailer, wherein the stopping boundary comprises a coupler boundary extending at a stopping distance from the coupler and a trailer boundary extending substantially perpendicular to the vehicle heading through the coupler position; and
  - controls a braking procedure in response to the hitch entering the stopping boundary.

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